Guide to Design of Reinforced Two-Way Slab Systems

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This guide presents analysis methods, design procedures, slab reinforcement and detailing practices, and strength and serviceability considerations, as well as information for the resistance to lateral forces for slab-column frames. It also covers the design for flexure and shear and torsion, as well as the effect of openings. Both two-way nonprestressed slabs and post-tensioned slabs are included.

Keywords: analysis method; deflection; direct design; flat plates; flat slabs; post-tension; reinforcement; shear; shearhead; slab-column frame; two-way slabs.

CONTENTS

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction: history of two-way slab system

Two-way flat slab construction in the United States evolved, and was invented and patented, in the early 1900s (Cohen and Heun 1979). Early two-way flat slab construction was built and subjected to load tests in place and scaled models were later tested in laboratories. While the amount of reinforcement in slab construction varied dramatically, flat slab systems were found to be economical for heavy live load occupancy. As the number of flat slab projects increased steadily worldwide, design rules were established and formalized (Sozen and Seiss 1963).

Prior to the 1950s, two-way waffle slabs and two-way flat slabs were designed and constructed with column capitals and some with drop panels. The hollow tile and concrete slab is a type of waffle slab that dates back to at least 1918 (Gamble et al. 1964). Column capitals were used to increase slab shear strength and drop panels to reduce the flexural reinforcement over columns, which allowed for thinner slabs. In the post-1970s era, field labor to construct formwork for column capitals and drop panels became costly; the introduction of reusable forms led to construction of flat plates, which are two-way flat slabs without column capitals or drop panels.

The lift-slab system for multistory construction was popular in the 1960s and 70s, but is no longer commonly used. The slabs were cast in a stack at ground level, post-tensioned, and then lifted to their final elevations using jacks lifting on steel collars embedded in the slabs.

Draped post-tensioning can be designed to balance part of the gravity loads. Combining unbonded post-tensioned tendons and nonprestressed reinforcement results in reduced slab thickness. In addition, the use of nonprestressed reinforcement supplements prestressed tendons to meet the required nominal strength and control slab cracking.

1.2—Scope

The performance record of various two-way slab systems is well established based on results of extensive tests and practical construction improvements in the twentieth century. The ACI Building Code permits design of slab systems, both nonprestressed and post-tensioned, based directly on fundamental principles of structural mechanics that satisfy equilibrium and compatibility. This guide provides classic solutions based on linearly elastic continuum, as well as prescriptive procedures used in common practice for analysis and design of slab systems. The fundamental principles in this guide are applicable to all planar structural slab systems subjected to gravity loads and, in certain conditions, those combined with lateral forces.

This guide addresses recommended practice in the selection and distribution of flexural reinforcement, and guidelines to transmit loads from slabs to columns by flexure, torsion, and shear. Detailing practices for post-tensioned two-way slabs are found in ACI 423.3R-05. This guide also discusses aspects and parameters where two-way slabs without beams are incorporated in ordinary or intermediate moment frames with ductile detailing and toughness.

While two-way slab systems have more than 100 years of service history, various practical refinements and research programs continue to develop new materials and technologies that support sustainable construction of two-way slabs.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

A_{cf} = larger gross cross-sectional area of the slab-column strips in the two orthogonal equivalent frames intersecting at a column in a two-way slab, ft^2 (m^2)

A_{sb} = area of reinforcement through the column core used as integrity reinforcement

b_1 = dimension of the critical section b_o measured in the direction of the span for which moments are determined, in. (mm)

b_2 = dimension of the critical section b_o measured in the direction perpendicular to b_1, in. (mm)

b_e = effective slab width, in. (mm)

b_o = perimeter of critical section at $d/2$ from face of support, in. (mm)

C = cross-sectional constant to define torsional properties of slab and beam

c_1 = dimension of rectangular or equivalent rectangular column, capital, or bracket measured in the direc-